This evaluation of the Barco 9200 LC LCD Light-Valve projection system is intended to quantify the performance of the projector as it is used in combination with a Stewart AM120 SN projection screen for demonstrating progressively scanned images of 1280 pixels x 1024 lines.

EVALUATION of the Barco 9200 LC LCD Light-Valve Projector

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at the
Sarnoff Corporation
CN 5300, Princeton, NJ 08543-5300

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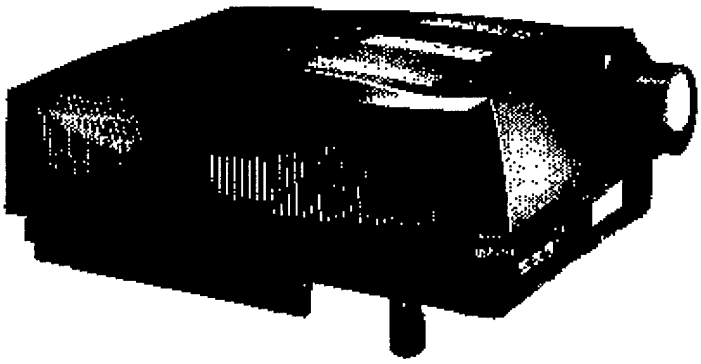

CONTENTS

FOREWORD

On behalf of the government user community, the *National Information Display Laboratory* (NIDL) has prepared this report, which discusses the performance of the following projection display:

Barco 9200 LC Projector and Stewart AM120 SN Screen

as one in a series of evaluations of projection displays. Such objective evaluations are essential to enable government users to obtain, at reasonable cost, projection displays with the required performance. The following summary pages give the reader an overview of the results.

A document that describes how the ANSI measurements are made, is available from the American National Standards Institute:

- ANSI Standard No. NAPM IT7.228-1996 Revision and Redesignation of ANSI IT7.228-1990, *American National Standard for Audiovisual Systems, Electronic Projection - - Fixed Resolution Projectors, October 1996,* American National Standards Institute, 11 West 42nd Street, New York, New York 10036.

Two companion documents that describe other measurement procedures are available directly from the NIDL and may also be accessed on the world wide web at http://www.nta.org/SoftcopyQualityControl/MonitorReports:

- NIDL Publication No. 171795-036, *Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20, Part 1: Monochrome CRT Monitor Performance, Draft Version 2.0, July 12, 1995.*

- NIDL Publication No. 171795-037, *Display Monitor Measurement Methods under Discussion by EIA (Electronic Industries Association) Committee JT-20, Part 2: Color CRT Monitor Performance, Draft Version 2.0, July 12, 1995.*

The NIDL procedures were developed in collaboration with the display industry and have been distributed for comments to EIA, ANSI, ASTM, ISO, and VESA Committees and have been exercised by the National Institute of Standards and Technology.

Other procedures are found in a draft standard being developed at the Video Electronics Standards Association:

- VESA FPDM136 Draft #7 Flat Panel Display measurements Standard (Proposal) Version 1.0P, Revision 0.0, November 10, 1997.

Comments, suggestions and questions about this report or the procedures used are welcome and encouraged. Depending on the user's specific application and budget, NIDL would be glad to make a display system recommendation. The NIDL can be reached at:

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COMPLETE SAMPLE SPECIFICATION

According to NAPM IT7228-1997
American National Standard for Audiovisual Systems
Electronic Projection - Fixed Resolution Projectors

Barco 9200 LC Light-Valve

Brand Model Specification based on measurements of	Barco 9200 LC Light-Valve November 1997	
	Measured	Advertised
Light output (illuminance) Lens ANSI Lumens	- 5652 (average of 9 points)	1.5:1 5000
Correlated color temperature	6000 K (approx.)	
Aspect ratio	4H:3V	
Light output uniformity, 13-points Brightest zone Dimmest zone	 +11% greater than 9-point average - 29% less than 9-point average	
Contrast ratio (4 x 4 Chessboard)	165 to 1	300 to 1
Blanking time Horizontal Vertical	3.152 µS. 584.7 µS.	
Resolution at light output (screen center)	Horizontal: 1280 at Dmod = 72% Vertical: 1024 at Dmod = 53%	
Response time (10% - 90%)	Not measured	
Input signal compatibility		RGB analog, BNC 75 ohms termination Composite video RS-232 for computer control S-XGA 15 pin HD
Chromaticity at screen center White Red Green Blue Chromaticity uniformity White relative to average screen	 u' = 0.1877 v' = 0.5043 u' = 0.4887 v' = 0.5242 u' = 0.1428 v' = 0.5730 u' = 0.1575 v' = 0.1708 ?u' = 0.005 ?v' = 0.004 ?u'v' = 0.005	
Audio Power Total harmonic distortion	Not measured Not measured	Not specified Not specified
Light source		1800 Watt metal-halide, 500 hours, user replaceable
Power (Input) Input voltage tolerance	Not measured Not measured	2300 Watts at 230 VAC

NIDL EVALUATION DATASHEET

Barco 9200 LC

I. MANUFACTURER'S DATA

Projector Manufacturer and Model	Barco 9200 LC Light-Valve, s/n 1110847
Price	$120,000
Monochrome or Color	Color
Screen Manufacturer and Model	Stewart AM120 SN, s/n 91SF10201001
Screen Gain	2.0 (Material: U-200/AMS Ultramatte 200)
Addressable Pixel Number	1280 x 1024
Screen Diagonal (viewable)	76.6 inches
Horizontal Scan Rate	76.966 KHz
Vertical Scan Rate	71.999 Hz, progressive
Viewing position, distance and angle	189 inches, ±6.9° Vert., ±9.2° Horiz.
Image Size (H x V) viewable	61.25 x 45.95 inches, (±7° Vert., ±9° Horiz.)
Pixel Size	47.9 x 44.9 mils

II. MEASURED PERFORMANCES

A. Performance Related to Illuminance of the Projector Only

Light Output (9-point average)	5211 lumens
Illuminance Nonuniformity of White	27% (2500 to 3440 Lux)
Illuminance Nonuniformity of Grey	58% at 1% Lmax (22.6 to 53.4 Lux)

B. Performance Related to Luminance of the Image on the Screen

Warmup Time	Not measured
Full-Screen Center Minimum Luminance	1.49 fL
Full-Screen Center Maximum Luminance	488 fL
Luminance Nonuniformity of White	62% (196 to 518 fL)
Luminance Nonuniformity of Gray	58% at 10% Lmax (19.63 to 42.22 fL)
Color tracking of grayscale from 1%Lmax to 100% Lmax	0.027 ? u'v' units
Contrast Ratio Full Screen Center	
excluding Halation effects	328:1
including Halation effects	100:1
Luminance Chessboard Contrast Ratio	165:1
CIE 1936 Chromaticity Coordinates of white	x = 0.334, y = 0.399
Chromaticity Uniformity* of full screen white	0.008 ? u'v' units relative to screen center
Chromaticity Uniformity of full screen gray	0.038 ? u'v' units at Lmin (0.729 to 1.465 fL)
Halation	< 0.7%
Crosstalk	15 %
System Gamma	1.94, white
Luminance Stability	< 1%, 11% to 100% full screen duty factor

C. Performance Related to Resolution of the Image on the Screen

NIDL pixels @ 50% Lmax	H-pixels	V-pixels
Text Threshold Cm=50%: Center	1280	1024
Periphery	1280	985
Screen avg	1280	989
Imagery Threshold Cm=25%: Center	1280	1024
Periphery	1280	1024
Screen avg	1280	1024

* Based on the CIE 1976 UCS Chromaticity Diagram: u' = 2x/(6y-x+1.5), v' = 4.5y/(6y-x+1.5)

Barco 7200 LC

– PERFORMANCE SUMMARY –

The projector excluding the screen produces light output (illuminance) of 5652 ANSI lumens at 1280 x 1024 ANSI pixel resolution.

Important performance characteristics of a projection display are resolution and light output. This projector and screen combination, as tested, exhibit the ability to display all of the number of pixels being addressed at 1280 x 1024. A contrast modulation (C_m) of 25% or more is clearly perceivable and appropriate for the display of imagery. A contrast modulation of 50% or more is appropriate for the display of small-size alphanumeric information. Based on contrast modulation measurements for 1-pixel-on/1-pixel-off, 2-on/2-off, and 3-on/3-off patterns displayed at 50% Lmax, the average number of resolvable pixels over the entire screen are determined by linear interpolation to be:

- 1280 x 1024 @ C_m = 25%
- 1280 x 989 @ C_m = 50%

SUMMARY COMMENTS ON NIDL EVALUATION DATASHEET

1. **Illuminance, Luminance and Chromaticity Uniformity:** The illuminance* measured directly into the projector varies by up to 20% across the image. The full white screen luminance** measured on the projection screen (screen gain = 2.0) varies by up to 104% from center to edge. Chromaticity variations ? u'v' across the white full screen were as great as 0.008 units (0.004 is visible) for a horizontal viewing angle of ±9°.

2. **Luminance Stability vs. Fill Factor:** No significant change in luminance was measured on the screen when the video fill factor (average picture level) was increased from 11% to 100% full screen.

3. **Contrast Modulation:** The average contrast modulation for 3-on/3-off white grille patterns at 50% Lmax was 96% x 95% (Horizontal x Vertical) for nine sampled screen locations. Contrast modulation for 2-on/2-off grille patterns averaged 91% x 89% (HxV) and averaged 71% x 64% (HxV) for 1-on/1-off grille patterns.

4. **Resolvable pixels:** Based upon the average contrast modulations determined at nine screen locations for 1-on/1-off, 2-on/2-off, and 3-on/3-off grille patterns at 50% Lmax, the number of resolvable pixels is linearly interpolated for C_m values of 25% and 50% to be:

   - 1280 x 1024 @ C_m = 25%
   - 1280 x 989 @ C_m = 50%

5. **Contrast ratio:** Full screen contrast ratio under dark room conditions measured at screen center is 100:1, including halation effects. Based upon the average luminance (in fL) of white and average illuminance of dark rectangular targets simultaneously projected in a 4 x 4 chessboard configuration (ANSI IT7.228 test pattern A.3) at 100% Lmax, the display contrast ratio reflected by the projection screen, is 153:1.

6. **System Gamma:** The value found for gamma is 1.94 for white.

7. **Halation:** Halation was only 0.7% on a small black patch surrounded by a large full white area.

8. **Crosstalk:** Luminance of a low-level gray screen changed by as much as 15% due to crosstalk effects concomitant with displaying a white box.

Notes:

* Illuminance (lux) refers to luminous flux from the projector. 1 lux = 1 lumen/square meter = 0.0929 footcandle.

** Luminance (fL) is a quantification of the brightness of a surface, in this case, luminous flux per unit solid angle per unit area emitted in a given direction from the surface of the front projection screen. 1 fL = 3.4263 candela per square meter (cd/m^2), 1 cd/m^2 = 1 lumen per steradian per square meter.

Example: A projector illuminance of 300 lux (27.9 footcandle) will lead to a screen luminance of 27.9 fL (95.6 candela per square meter), assuming the screen scatters light uniformly in all directions and does not absorb any light, i.e., screen gain = 1.

Section I
INTRODUCTION

The present study evaluates a production unit of the *Barco 9200 LC* high-resolution color LCD light-valve projector and *Stewart AM120 SN* projection screen. Only photometric measurements were performed on this system. The primary emphasis of the measurements is the determination of the contrast modulation of the display for on/off grille patterns. In turn, the contrast modulation measurements provide an estimate of the number of resolvable pixels the that are displayed on the projection screen. The number of *resolvable* pixels is typically less than the addressability of the display, which is the number of positions that are electronically *addressed.*

We provide below a description of the display that was evaluated and the details of the setup procedures used to prepare the display for measurement. Section II presents the data and results of the photometric measurements. Section III completes the report with analyses of the measurements and final conclusions.

The procedures and calibrations used in the measurements are detailed in the following ANSI standard:

> ANSI Standard No. NAPM IT7.228-1996 Revision and Redesignation of ANSI IT7.228-1990, *American National Standard for Audiovisual Systems, Electronic Projection - - Fixed Resolution Projectors, October 1996,* American National Standards Institute, 11 West 42nd Street, New York, New York 10036.

Other procedures used are found in NIDL documents:

> NIDL Publication No. 171795-036, *Display Monitor Measurement Methods under discussion by EIA (Electronic Industries Association) Committee JT-20, Part 1: Monochrome CRT Monitor Performance, Draft Version 2.0,* July 12, 1995.

and

> NIDL Publication No. 171795-037, *Display Monitor Measurement Methods under discussion by EIA (Electronic Industries Association) Committee JT-20, Part 2: Color CRT Monitor Performance, Draft Version 2.0,* July 12, 1995.

Other procedures are found in a draft standard currently being developed at the Video Electronics Standards Association:

> VESA FPDM136 Draft #7 Flat Panel Display measurements Standard (Proposal) Version 1.0P, Revision 0.0, November 10, 1997.

A. The Barco 9200 LC

The projection system was set up with the following photometric and electrical parameters to display images at 1280 x 1024 addressable pixels:

Photometric Parameters:

- Display format is addressable pixels.
- Raster size is 61.25 x 45.95 inches
- Addressable pixel size is 47.9 x 44.9 mils.
- Full screen luminance of white is 488 fL at screen center.
- Full screen luminance of black is 1.49 fL at screen center.

Electrical Parameters:

- Line rate is 76.966 kHz.
- Frame rate is 71.999 Hz, progressive (non-interlaced).
- Video data rate is 130.074 MHz
- Pixel time is 7.687 nsec.
- Total line period is 1690 pixels
- Total frame period is 1069 lines.
- H-blanking period is 3.152 μS.
- V-blanking period is 584.7 μS.

B. INITIAL DISPLAY SETUP

The display was set up in NIDL's display measurement facility using numerous controls accessible to the user on the menu driven remote control provided with the projector. A representative of Barco performed the setup procedure and certified that the adjustments were in accordance with their specifications. *Brightness* and *Contrast* controls were adjusted to achieve visually distinguishable steps at both low and high luminance levels of the SMPTE RP-133 gray-scale test pattern. Other adjustments were made including *Convergence*, *Size*, and *Trapezoid.* Focus and black level uniformity adjustments were also made by the Barco representative.

With the screen commanded to black (zero count level), the background raster, Lmin, was measured to be 1.49 fL. Then, with the screen commanded to full white (255 count level), the maximum luminance, Lmax, was measured to be 488 fL at screen center. Full correction of black level luminance uniformity was not possible within the limited range of the available dynamic zone correction.

All photometric measurements are taken from the a single viewing direction instead of from infinity. Spatial resolution measurements were taken a close as possible to normal to the surface of the screen at each of the nine screen test locations, and directly into the projector lens for the ANSI pixel measurements.

Section II
COLORIMETRIC MEASUREMENTS

Reference: Color CRT Monitor Performance, Draft Version 2.0 Section 3.0, page 9.
ANSI Standard No. NAPM IT7.228-1996.

Instruments used in these measurements included:

- Photo Research SpectraScan PR-704 spectroradiometer, 0.5° aperture
- Photo Research Pritchard-1980A-CD photometer , 1° and 20' apertures
- Microvision Superspot 100 Display Characterization System with OM-1 optic module (linear photodiode array with photopic filter) imaging through a JML optical Japan lens, 4 3/8, f = 4.5, assembled for working distance of 36 inches.
- Graseby Optronics S370 Optometer with Model 268P illuminance sensor.
- Quantum Data 8701 test pattern generator, 400 MHz pixel-rate

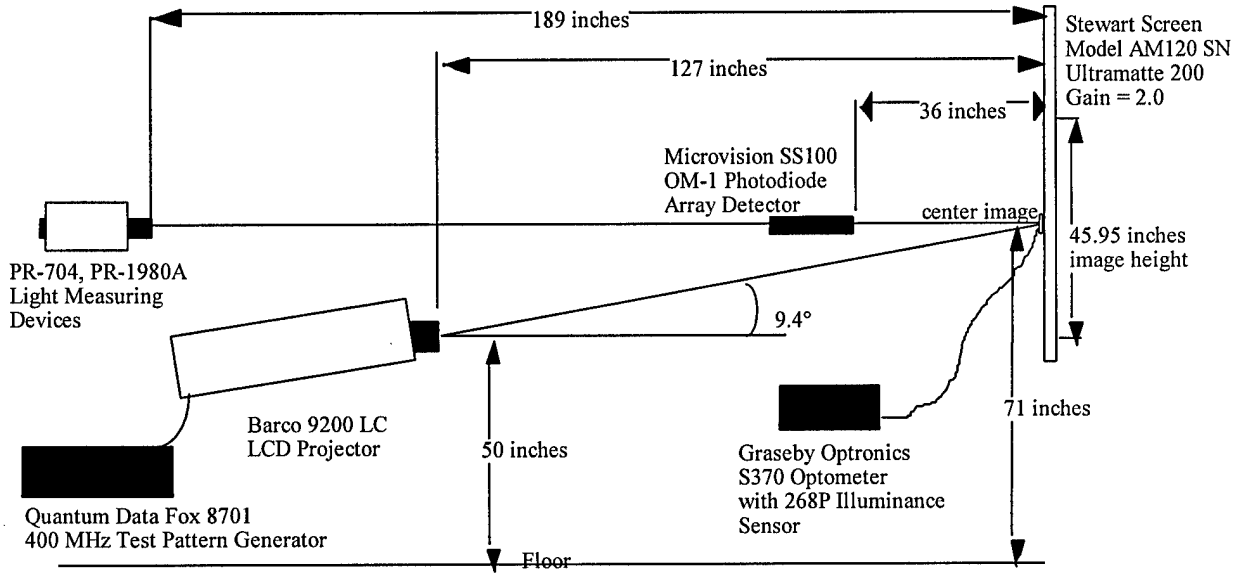

Fig. II-1. Test set up.

A. ILLUMINANCE, LUMINANCE AND CHOMATICITY UNIFORMITY

Reference: Color CRT Monitor Performance, Version 2.0 Section 4.4, page 11.
ANSI Standard No. NAPM IT7.228-1996.

The illuminance varies by up to 27% across the screen. The full screen luminance varies by up to 62% across the screen at the highest luminance setting. Chromaticity variations, ? u'v' across a white full screen were as great as 0.008 units (0.004 is visible).

Illuminance measured according to the ANSI procedure yielded 5,652, +11%, -9% ANSI lumens. The variation in full screen illuminance (lux) was found to be as much as 18% for the thirteen ANSI screen locations shown in Figure II.A-1.

Illuminance, luminance, and chromaticity coordinate measurements were also taken at nine screen positions shown in Figure II.A-2 for the maximum luminance for a full white field and at five screen positions for the Quantum Data Fox "Brightness" test pattern. The data are shown in Table II.A-2 on the next page and in Figures II.A-3 through II.A-5 on the following page. For each of the test patterns, the center position showed the highest illuminance. From a single viewing point, the entire screen is contained within ±7° vertically and ±9° horizontally the full white illuminated projection screen with gain of 2.0 (specified by the manufacturer) exhibited slightly higher luminance (fL) at the 6:00 lower-center screen position.

With the "Brightness" test pattern displayed at the highest luminance level measured, the largest departures from the chromaticity of the center occurred at the 4 o'clock lower-right corner position and reached 0.008 ?u'v' units. The results are shown in Fig. II.A-5 in terms of the chromaticity error.

Uniformity of illuminance, luminance and chromaticity coordinates are computed using measurements of nine screen positions for various grayscale luminance settings: Lmin, 1% Lmax, 10% Lmax, and 50% Lmax. The data are shown in Table II.A-1 and in Figures II.A-6 through II.A-11 on the following pages.

Maximum illuminance nonuniformity of 58% occurred at the 1% Lmax dark gray luminance level. Maximum luminance nonuniformity of 62% occurred at full white screen (100% Lmax). Chromaticity nonuniformity was maximum when the full screen luminance was at Lmin, and reached as high as 0.038 units ?u'v'.

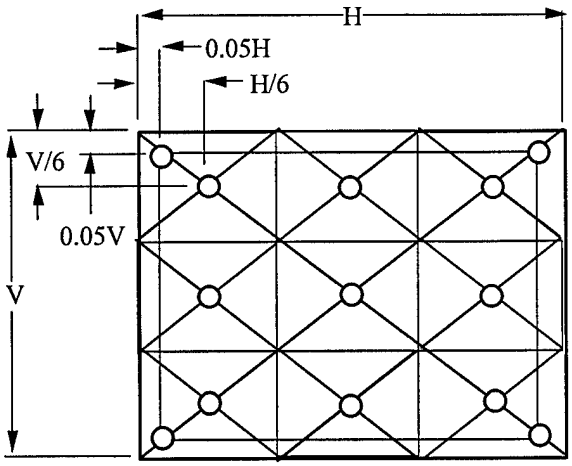

Fig. II.A-1 ANSI screen locations for measurement of light output in ANSI lumens.

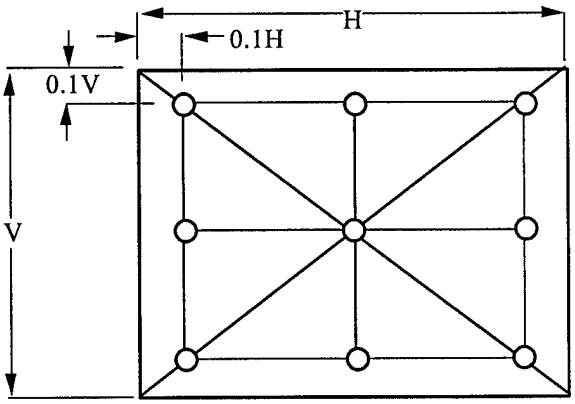

Fig. II.A-2 Nine screen locations specified in ISO, IEC, ANSI-HFES, EIAJ, and VESA standards for measurement of spatial uniformity of illuminance, luminance and chromaticity.

Table II.A-1. Spatial Uniformity of Grayscale Luminance and Chromaticity for 1280 x 1024 Format

Results of Illuminance (in Lux), Luminance (in fL) and CIE Chromaticity measurements taken at nine screen positions for full screens at Lmin, 1% Lmax, 10% Lmax, 50% Lmax and 100% Lmax.

	Luminance of Full Screen				
Nonuniformity	Lmin	1% Lmax	10% Lmax	50% Lmax	100% Lmax
Illuminance (Lux)	57%	58%	55%	40%	27%
Luminance (fL)	50%	40%	58%	56%	62%
Chromaticity (? u'v' units)	0.038	0.020	0.011	0.009	0.008

Table II.A-2. Spatial Uniformity of Luminance and Chromaticity for 1280 x 1024 Format

Illuminance (in Lux) and luminance (in fL) taken at five and nine screen positions for 100% Lmax.

Quantum Data FOX "Brightness" test pattern

Illuminance of projector (in Lux)

2440		2300
	3300	
2460		2100

Luminance from screen (in fL)

197		156
	482	
245		204

Full Screen

Illuminance (in Lux) for white

2655	3160	2670
3000	3440	2890
2620	3150	2500

Luminance (in fL) of white

215	282	196
291	488	268
270	518	249

Illuminance (in Lux) for black

12.5	15.6	10.2
15.0	10.1	13.6
12.5	7.4	12.1

Luminance (in fL) of black

1.13	1.43	0.81
1.50	1.49	1.24
1.32	1.20	1.20

Illuminance (in Lux) at ANSI screen points

2940	3270	2980
3180	3490	3250
2950	3370	2860

Projector Lumens at ANSI screen points

5286	5879	5358
5718	6275	5843
5304	6059	5142

Illuminance* of Projector for full white

min	2500 lux
max	3440 lux
nonuniformity (relative to center)	27 %
Avg. screen	2898 lux
Screen area	1.80 square meters
Avg. Luminous flux	5211 lumens
ANSI Lumens	5652 +11%, -9%

Luminance of Screen for full white**

min	196 fL
max	518 fL
nonuniformity (relative to center)	62 %
Avg screen	309 fL
Screen gain	2.0
Viewing angle	±7° vertical
	±9° horizontal

Notes:

* Illuminance (lux) refers to the amount of light falling upon a surface, in this case, luminous flux from the projector incident on the surface per unit area of the front projection screen. 1 lux = 1 lumen/square meter = 0.0929 footcandle.

** Luminance (fL) is a quantification of the brightness of a surface, in this case, luminous flux per unit solid angle per unit area emitted in a given direction from the surface of the front projection screen. 1 fL = 3.4263 candela per square meter (cd/m^2), 1 cd/m^2 = 1 lumen per steradian per square meter.

Example: A projector illuminance of 300 lux (27.9 footcandle) will lead to a screen luminance of 27.9 fL (95.6 candela per square meter), assuming the screen scatters light uniformly in all directions and does not absorb any light.

Barco 9200 LC projector and Stewart AM120 projection screen

1280 x 1024

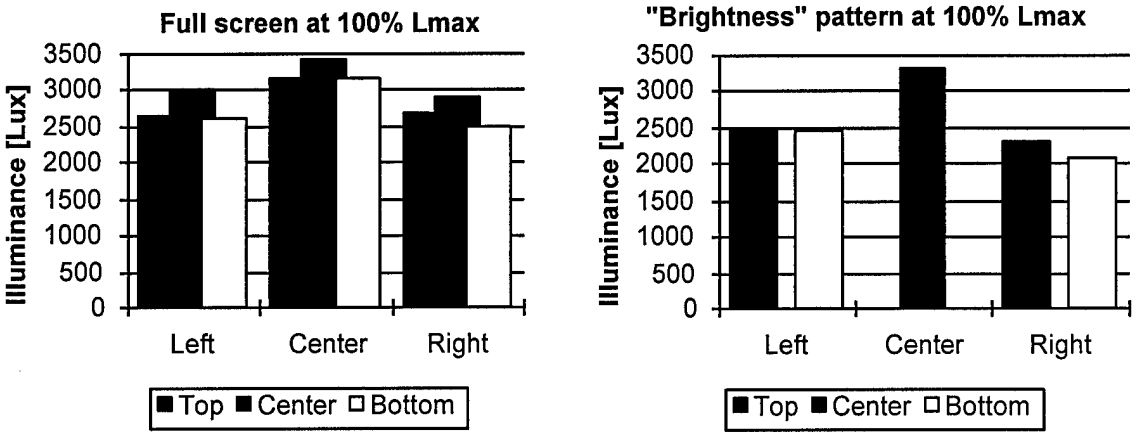

Fig. II.A-3 Spatial Uniformity of Illuminance

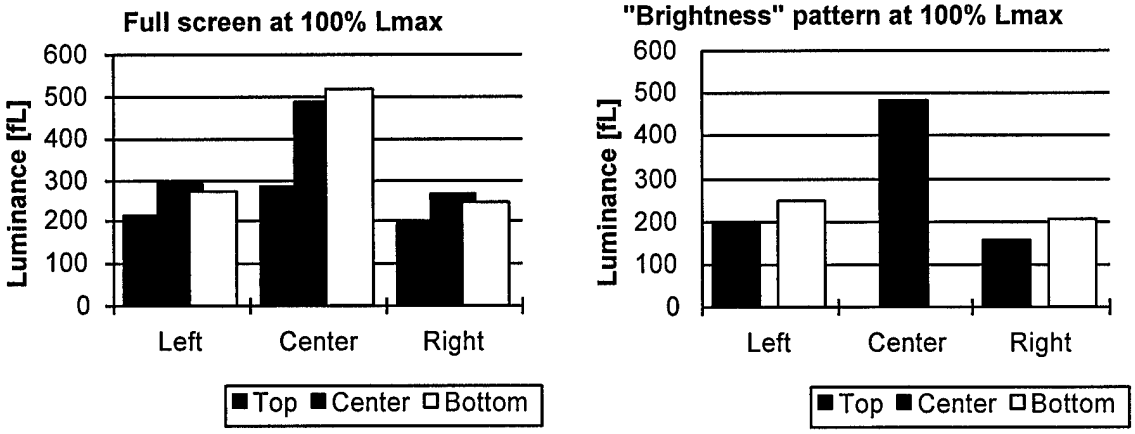

Fig. II.A-4 Spatial Uniformity of Luminance.

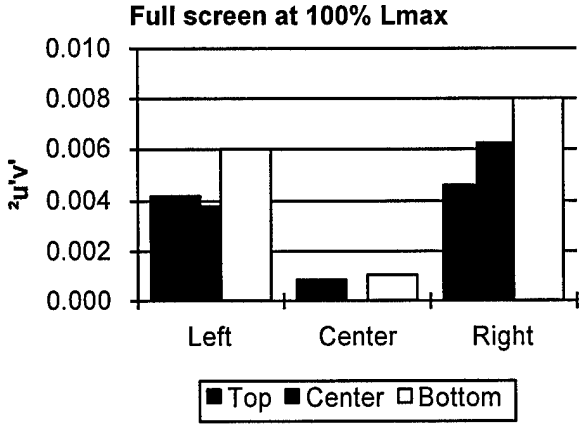

Fig. II.A-5 Spatial Uniformity of Chromaticity (vs. Center)
A chromaticity error, ?u'v', of 0.004 is visible.

Barco 9200 LC projector and Stewart AM120 projection screen

1280 x 1024

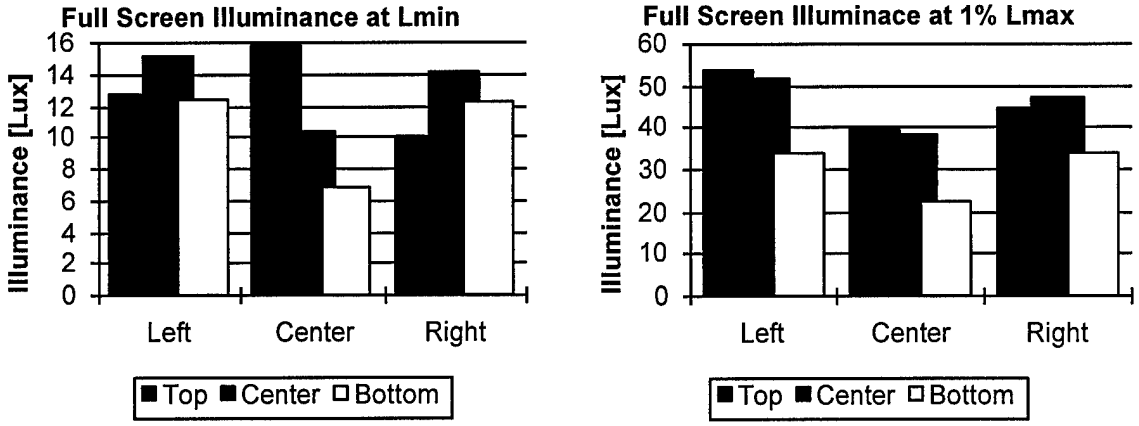

Fig. II.A-6 Spatial Uniformity of Illuminance

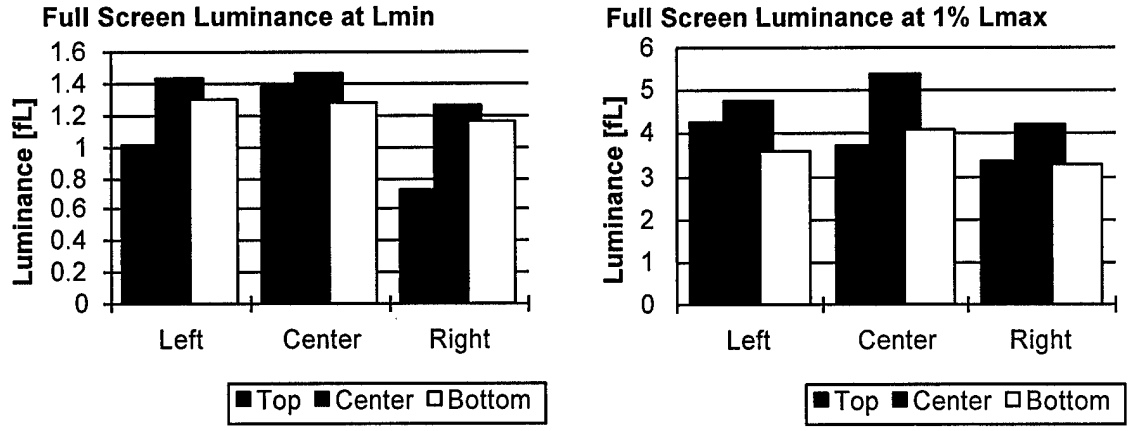

Fig. II.A-7 Spatial Uniformity of Luminance.

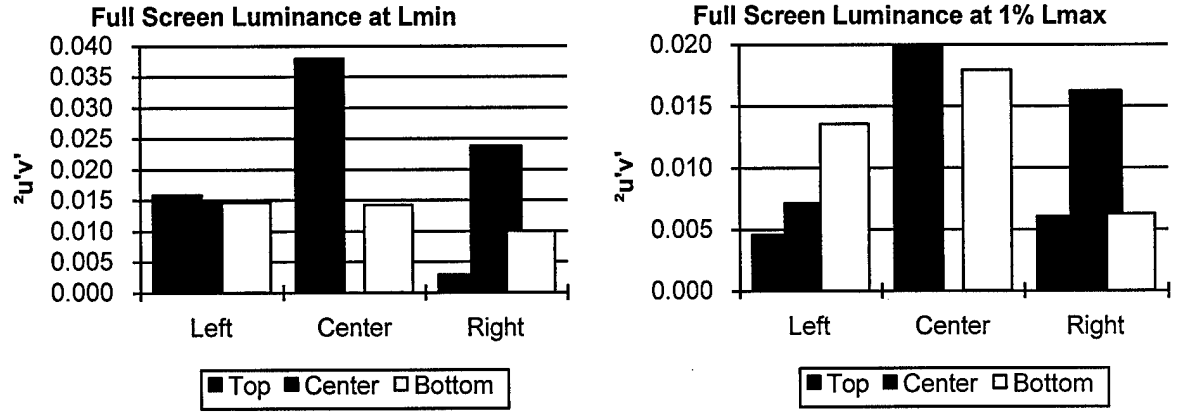

Fig. II.A-8 Spatial Uniformity of Chromaticity (vs. Center)
A chromaticity error, ?u'v', of 0.004 is visible.

Barco 9200 LC projector and Stewart AM120 projection screen

1280 x 1024

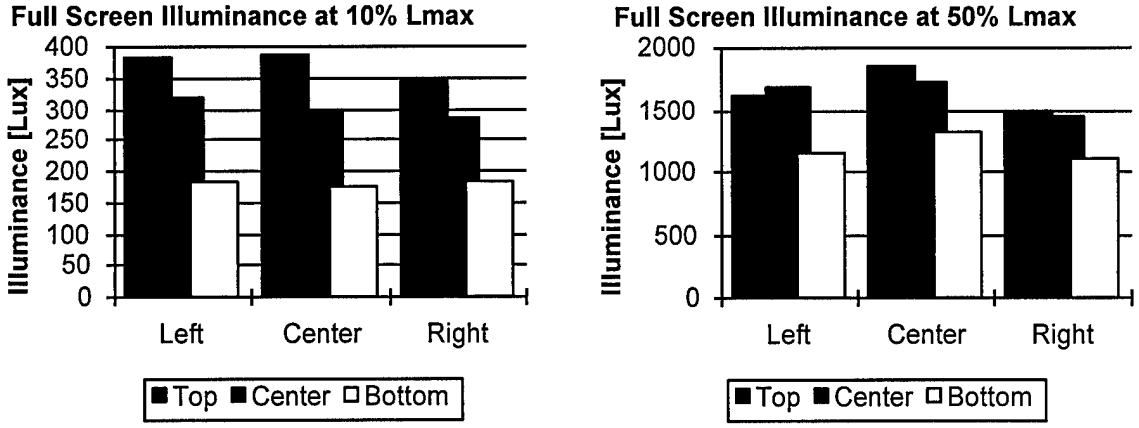

Fig. II.A-9 Spatial Uniformity of Illuminance

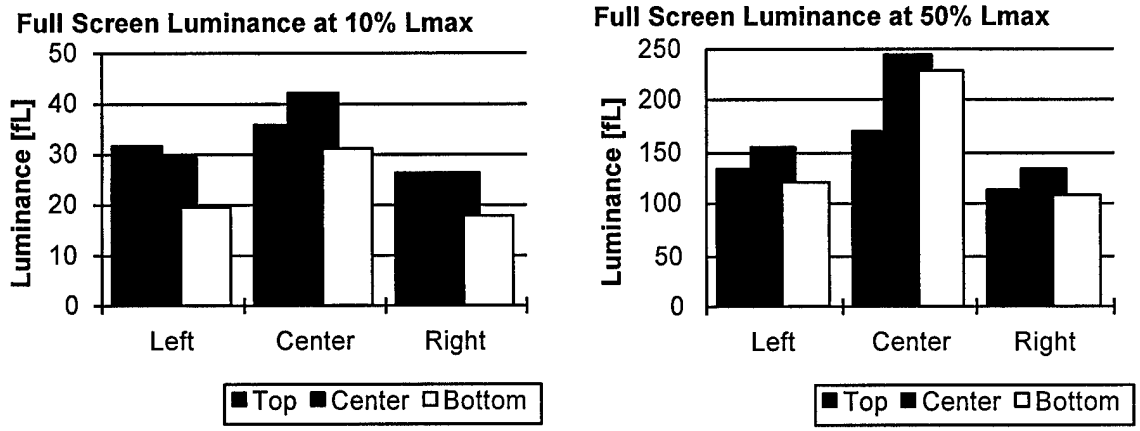

Fig. II.A-10 Spatial Uniformity of Luminance.

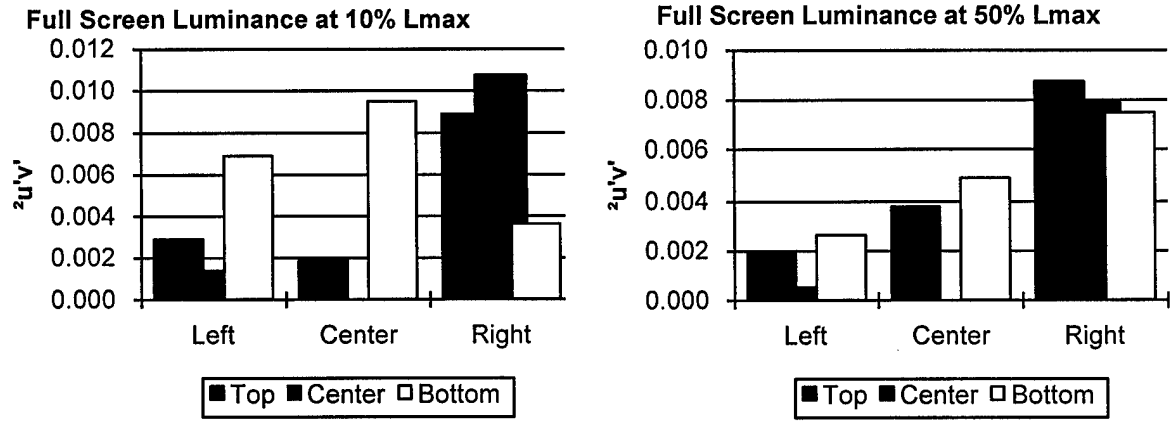

Fig. II.A-11 Spatial Uniformity of Chromaticity (vs. Center)
A chromaticity error, ?u'v', of 0.004 is visible.

B. LUMINANCE STABILITY VS. FILL FACTOR

Reference: Color CRT Monitor Performance, Draft Version 2.0 Section 4.3, page 11.

There is no significant change in luminance with increasing fill factor from 11% to full screen.

Center screen luminance was measured for white patches on a black background (Quantum Data "Brightness" test pattern) and for the full screen. The change in center screen luminance with increasing fill factor (increasing percentage of screen that is white) is negligible, less than 1%.

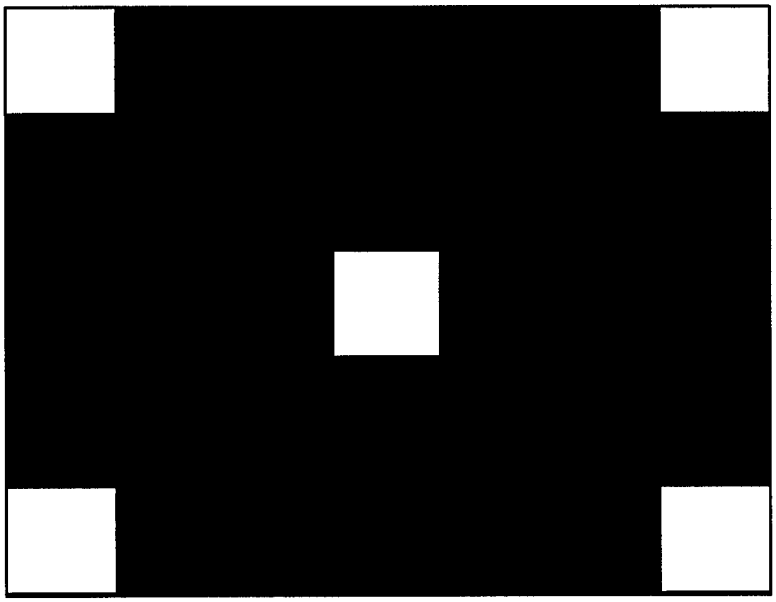

Fig. II.B-1 Quantum Data "Brightness" test pattern with 11% duty factor depicted as projected onto the Stewart AM120 SN screen using the Barco 9200 LC projector.

C. CONTRAST MODULATION

Reference: Color CRT Monitor Performance, Draft Version 2.0 Section 5.2, page 23.

The average contrast modulation for 3-on/3-off white grille patterns at 50% Lmax was 96% x 95% (HxV) for nine sampled screen locations. Contrast modulation for 2-on/2-off grille patterns averaged 91% x 89% (HxV) and averaged 71% x 64% (HxV) for 1-on/1-off grille patterns.

Contrast modulation was measured in both horizontal and vertical directions at nine screen positions for white. The screen luminance was commanded to 50% maximum level. Four video modulation frequencies were examined using full screen grille test patterns consisting of alternating lines with n pixels on, n pixels off (n=1,2,3,4).

The contrast modulation values for white grilles at screen center and averaged over the eight peripheral screen positions are presented in Figure II.C-1.

The 1280 x 1024 data is displayed in Table II.C-1. The contrast modulation, C_m is reported (the defining equation is given in the Table). For all 2-on/2-off horizontal and vertical grilles the C_m is exceptionally good (ranging from 75% to 99%, and the grilles are readily resolved over the entire screen. For the 1-on/1-off grille patterns, the modulation is also very good, but dropped as low as 38% at the upper right corner of the screen.

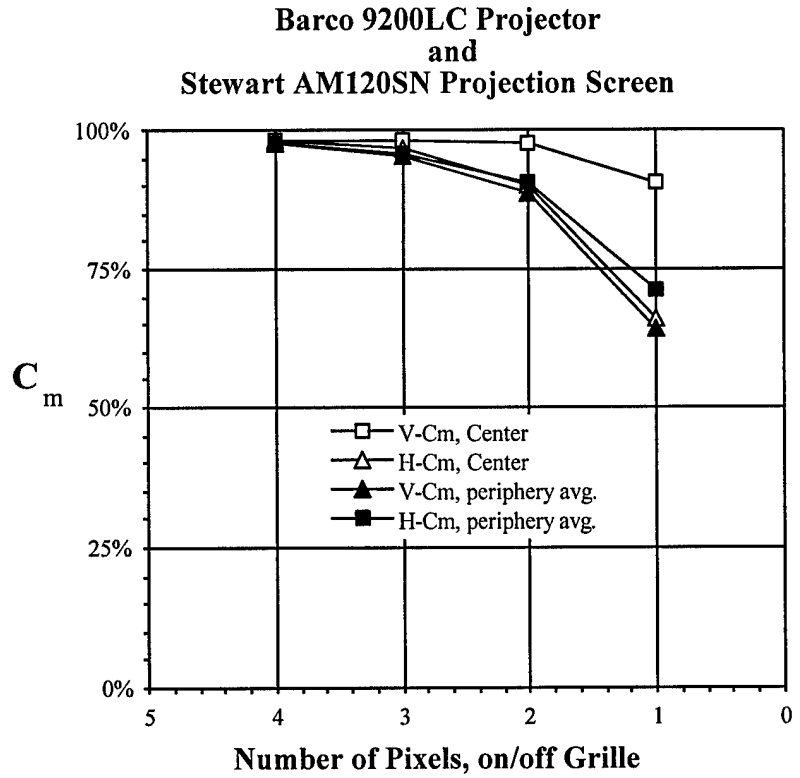

Fig. II.C-1 Plot of contrast modulation of white grilles at screen center obtained from test results for the 1280 x 1024 format.

Table II.C-1. Contrast Modulation

Contrast Modulation (in %) at nine screen positions for four frequencies.

$C_m = (L_{peak} - L_{valley})/(L_{peak} + L_{valley})$

Screen positions as indicated by position of data on page.

n x n indicates lines n pixels wide separated by n-pixel spaces (n-on / n-off).

Microvision OM-1 optic module used with Canon TV Zoom lens.

H = modulation in horizontal direction (vertical bars); V= modulation in vertical direction (horizontal bars).

C_m (%) - White at 50% Lmax for 1280 x 1024 Format

Screen luminance at 50% Lmax.

n x n	Hgrille V-Cm	Vgrille H-Cm	Hgrille V-Cm	Vgrille H-Cm	Hgrille V-Cm	Vgrille H-Cm
4	97%	97%	97%	97%	98%	98%
3	93%	95%	94%	95%	91%	97%
2	82%	88%	86%	99%	75%	88%
1	46%	62%	52%	83%	38%	70%
4	97%	97%	98%	98%	98%	98%
3	93%	95%	98%	97%	99%	97%
2	93%	89%	98%	90%	91%	95%
1	84%	61%	91%	66%	86%	82%
4	97%	97%	98%	98%	97%	98%
3	92%	95%	98%	95%	99%	93%
2	81%	89%	95%	84%	96%	94%
1	43%	73%	72%	63%	66%	80%

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D. CONTRAST RATIO

Reference: ANSI Standard No. NAPM IT7.228-1996.

Full screen luminance contrast ratio is 100:1 at screen center, including halation effects under dark room conditions. The average luminance contrast ratio for the ANSI 4 x 4 chessboard patterns displayed at 100% Lmax was 153:1 over the projection screen.

Luminance was measured in both horizontal and vertical directions at 16 screen positions for white and black rectangular targets simultaneously displayed in a 4 x 4 chess board configuration as specified by ANSI IT7.228. The screen luminance was commanded to 100% maximum level.

The data is displayed in Table II.D-1. The contrast ratio, CR is reported (the defining equation is given in the Table).

Contrast ratio computed from measurements made under dark room conditions for full screen white (488 fL) and black (1.49 fL) is reduced from 328:1 to 100:1 when halation effects of 0.7% are included.

1280 X 1024

Table II.D-1. Contrast Ratio = (L_{white} / L_{black})

Screen positions as indicated by position of data on page.

ANSI Chessboard Luminance (in fL) Includes projection screen.

230	1.98	283	1.54
1.62	398	2.13	258
316	4.05	491	2.42
1.60	506	2.53	259

	Luminance of projector and screen
Avg white	342.6 fL
Avg black	2.234 fL
Avg CR	153
Min black	1.54 fL
Max black	4.05 fL
Nonuniformity	62 %
Min white	230 fL
Max white	506 fL
Nonuniformity	55 %
Min CR	57
Max CR	329
Nonuniformity of CR	83 %

E. SYSTEM GAMMA

Reference: Color CRT Monitor Performance, Version 2.0 Section 4.2, page 11.

The value found for gamma of white is 1.94.

Luminance at center screen for a 100% full screen size box was measured twenty different input counts. Table II.D-1 shows the data. Figures II.E-1 and II.E-2 illustrate the white luminance and chromaticity data, respectively. The system gamma is defined as the slope of the curve in the log-log plot. Since the curve is nonlinear, a unique value of gamma does not exist. A single value was derived for the high-end luminance range.

The gamma value obtained for white in 1280 x 1024 format was 1.94 from about 5.54 fL to 488 fL (23 to 255 counts).

The maximum shift in chromaticity of the whitepoint occurred for 1280 x 1024 format around 0.35% Lmax (1.7 fL) and exceeded 0.030 ?u'v' units relative to 100% Lmax (488 fL). ?u'v' of 0.004 units is noticeable.

Table II.E-1. System Gamma

Luminance (in fL) of projector and screen at center screen as a function of input counts.

Input level Counts	Full Screen 1280 x 1024 L (fL)	CIE x	CIE y	CCT °K
Black, 0	1.45	0.3154	0.3689	n.a
1	1.48	0.3201	0.3669	n.a
2	1.51	0.3255	0.3668	5769
3	1.54	0.3309	0.3658	5566
7	1.7	0.342	0.3493	5113
15	3.26	0.3313	0.3566	5549
23	5.54	0.3339	0.3517	5439
31	8.43	0.3302	0.3579	5592
39	12.1	0.3292	0.3629	5630
47	16.4	0.3259	0.3621	5757
63	27	0.322	0.3633	5914
79	42.7	0.321	0.3711	n.a
95	61.4	0.3219	0.3698	n.a
111	85.4	0.3231	0.3719	n.a
127	116	0.3209	0.372	n.a
143	151	0.321	0.3719	n.a
159	194	0.3217	0.3725	n.a
191	301	0.3216	0.3769	n.a
223	418	0.3268	0.3864	n.a
White, 255	488	0.334	0.3988	n.a
Red, 255	60.9	0.6720	0.3204	n.a
Green, 255	401	0.3485	0.6215	n.a
Blue, 255	25.7	0.1388	0.0669	n.a

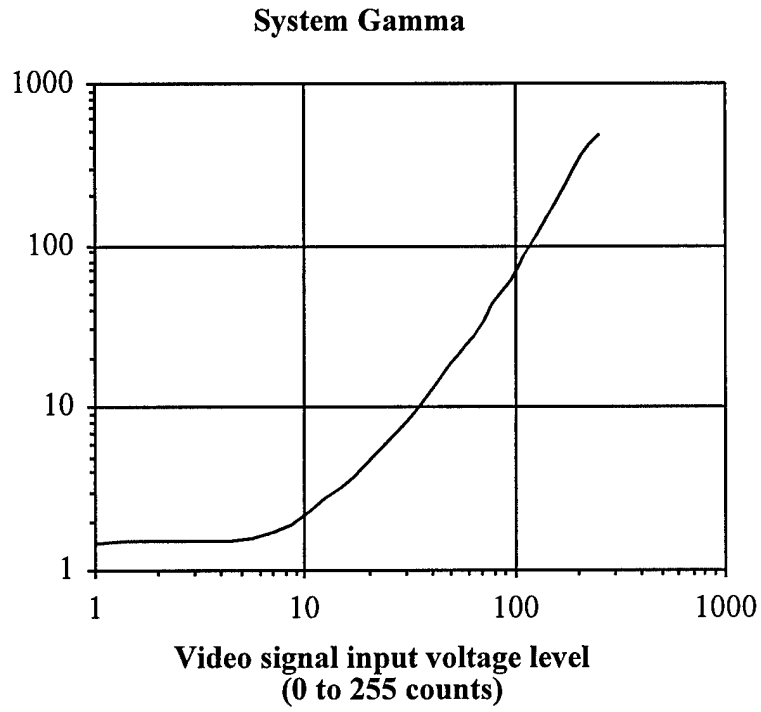

Fig. II.E-1. Log-log plot of input counts versus luminance for a white full screen.

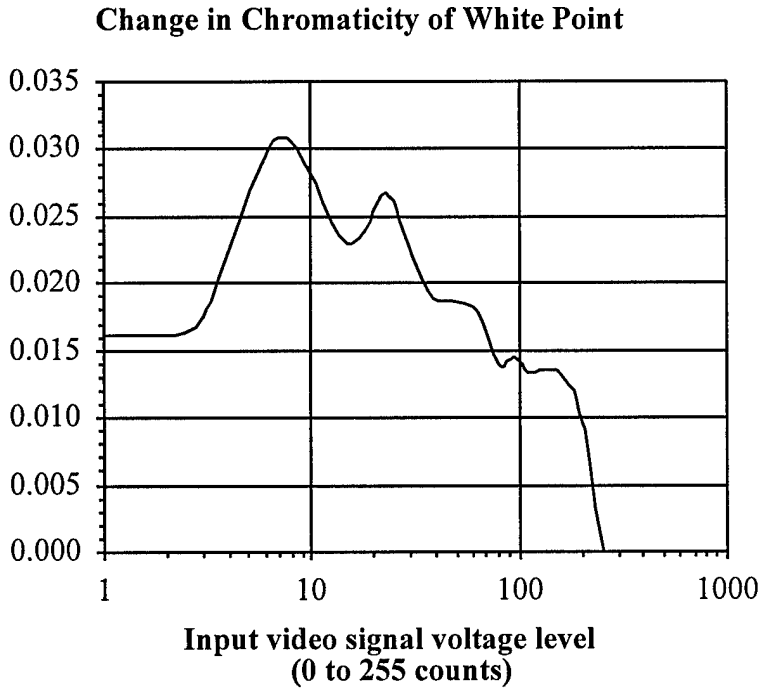

Fig. II.E-2. Plot of input counts versus chromaticity shift in ?u'v' units relative to white full screen at Lmax (input count 255).

F. HALATION

Reference: Color CRT Monitor Performance, Draft Version 2.0 Section 4.6, page 16.

Halation was only 0.7% on a small black patch surrounded by a large full white area.

Halation is the phenomenon by which the luminance of a given region of the screen is improperly increased by contributions from surrounding more luminous areas. Sources of halation include light scattering within the CRT phosphor layer and internal reflections inside the glass faceplate and the projector lens assembly. Halation is undesirable as it degrades the contrast of displays.

Halation is determined by measuring the luminance, L_b, of a small (50 pixels wide, approximately 0.2% of the screen area) square commanded to L_{min} when surrounded by an otherwise full white screen (1280 x 1024 pixels) commanded to L_{max}. In this case, full screen L_{max} is equal to 488 fL while full screen L_{min} is only 1.49 fL. Halation is then defined numerically as:

$$\% \, Halation = 100 \, x \, (L_b - L_{min}) / L_{max},$$

where L_{max} is the full screen white luminance, L_{min} is the full screen black luminance, and L_b is the measured luminance of the small square when the surrounding image area is commanded to white at L_{max}.

The measured data and derived values of halation are presented in Table II.K-1. The luminance of the small black square is seen to increase by 0.7% Lmax when as the outer bright patch is displayed at L_{max}.

Table II.K-1. Halation

Lmin(fL)	Lmax (fL)	Lb(fL)	% Halation
1.35	448	4.3	0.7

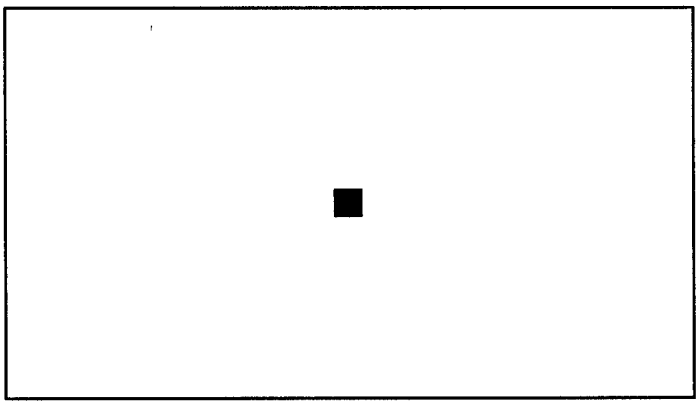

Fig. II.F-1. Halation test pattern: 50-pixel wide black square on full white background.

G. CROSSTALK

Reference: VESA FPDM136 Draft #7 Flat Panel Display measurements Standard (Proposal) Version 1.0P, Revision 0.0, November 10, 1997.

Luminance of a low-level gray screen changed by as much as 15% due to crosstalk effects concomitant with displaying a white box.

Crosstalk is the phenomenon by which the luminance of a given region of the screen is improperly effected by contributions from adjacent areas of different luminance.

Background Luminance (fL)		
Box ON	Box OFF	Change
5.90	5.13	15%

Table II.F-1. Crosstalk Data

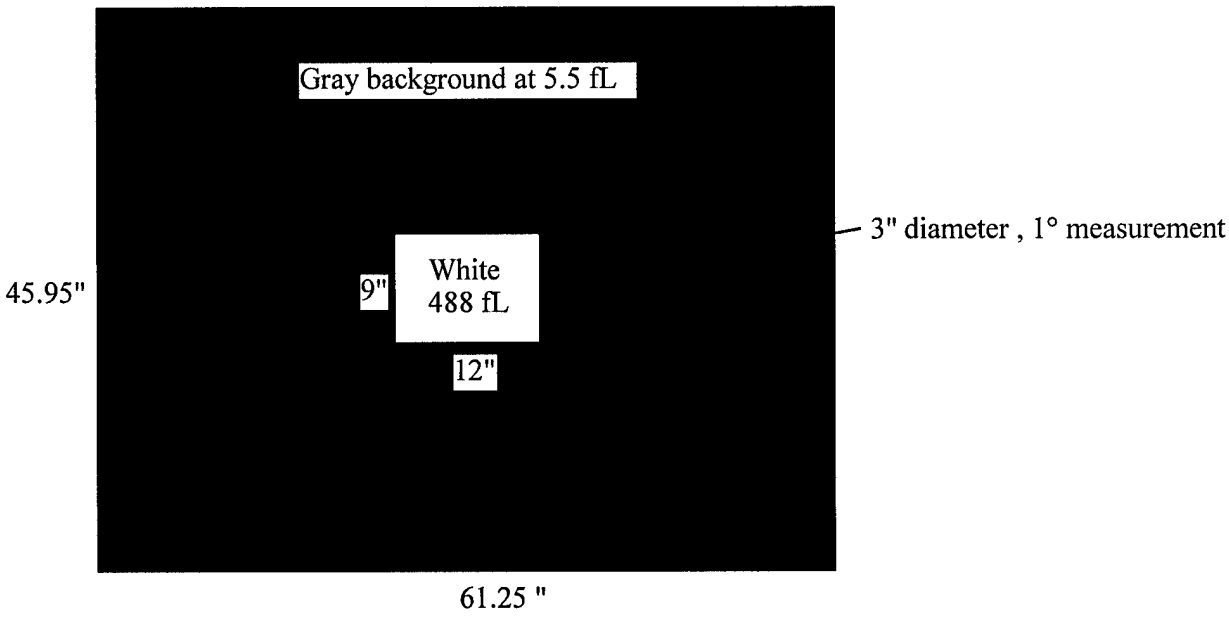

Fig. II.G-1. Worst-case crosstalk test pattern: medium size white rectangle on gray background.

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Section III
ANALYSIS AND CONCLUSIONS

The most important performance characteristic of a projection display is resolution. Measures of resolution include the contrast modulation at the stated addressability and the number of resolvable pixels. At its tested addressability of 1280 x 1024 pixels, the Barco 9200 LC projector and Stewart AM120 SN projection screen achieves a nine-point average white contrast modulation of 68% over the screen. Using linear interpolation and the contrast modulation measurements for 1-on/1-off, 2-on/2-off, and 3-on/3-off patterns, the number of resolvable pixels at 50% Lmax is:

- 1280 x 1024 @ C_m = 25%
- 1280 x 989 @ C_m = 50%

A contrast modulation of 25% or more is clearly perceivable and appropriate for the display of imagery. A contrast modulation of 50% or more is appropriate for the display of small-size alphanumeric information.

For 1280 x 1024 format, the 2-on/2-off grilles (horizontal and vertical, of Table II.C-1) exhibited measured C_m values exceeding 75% in most places, showing that information at these frequencies is definitely resolved. For the white 1-on/1-off grilles, the Cm values fall as low as 38% in areas along the top edge of the screen.

A potential contribution to the loss of contrast modulation is misconvergence. The principal effect of misconvergence is the effective broadening of white lines. The misconvergence of the Barco 9200 LC projected image was visually assessed to be on the order of less than one pixel size (47.9 x 44.9 mils) at all locations on the screen. Misconvergence >1.5 to 2 pixels can significantly degrade resolution. Misconvergence < 1.0 pixel is typically not an important factor because the relative perceived luminosities of red and blue are considerably less than that of green.

APPENDIX A
DEFINITIONS - MEASUREMENT TERMS

Addressability: Measure of the accuracy with which an electron beam spot is placed at discrete positions on the screen. The inter-pixel distance [TEP 192]. Defines how precisely one can position the electron beam spot on the screen.

ANSI Lumen Quantification of visible light power (in lumens) of a projection display, defined in ANSI standard IT7.228 as the average of nine illuminance values in lux measured at specified locations within the projected image area, multiplied by the area of the image in square meters.

ANSI Pixel Quantification of display resolution in pixels of a projection display, defined in ANSI standard IT7.228 as the highest spatial frequency (or greatest number of pixels) which does not degrade modulation depth below 30% of the low-frequency modulation depth, specifically that of the 4 x 4 checkerboard pattern. The modulation depth is defined in IT7.228 as the (peak - valley) luminance of a 1-on/1-off grille relative to the average (white - black) luminance of the ANSI large-area 4 x 4 checker board test pattern.

Chromaticity Uniformity Measure of how chromaticity vary across the screen. Chromaticity should be as uniform as possible.

Contrast Modulation (Cm): A measure of relative luminances, L_{peak}, L_{valley}, over a distance of multiple cycles of high and low states in a displayed grille test pattern.

Monitors with contrast modulation greater than 25% are generally acceptable for the display of images while the display of text generally calls for contrast modulation greater than 50%.

Contrast Ratio (CR) The ratio of a higher luminance to a lower luminance.

Convergence: Measure of the separation in landing positions of separate beams directed toward the same point on the screen. The main misconvergence errors involve blue-to-red separations and green-to-red-blue-average separations (coma), and are measured in both horizontal and vertical directions. Misconvergence errors exceeding pixel size degrade contrast modulation and may cause spurious color fringes at edges in images.

Halation Phenomenon by which the luminance of a given region of the screen is improperly increased by contributions from surrounding more luminous areas. Sources of halation include light scattering within the CRT phosphor layer and internal reflections inside the glass faceplate and the projector lens assembly. Halation is undesirable as it degrades the contrast of displays.

Illuminance	Refers to the amount of light falling upon a surface, in this case, luminous flux from the projector incident on the surface per unit area of the front projection screen. 1 lux = 1 lumen/square meter = 0.0929 footcandle.
Luminance	A quantification of the brightness of a surface, in this case, luminous flux per unit solid angle per unit area emitted in a given direction from the surface of the front projection screen. 1 fL = 3.4263 candela per square meter (cd/m^2), 1 cd/m^2 = 1 lumen per steradian per square meter.
Minimum Luminance (Lmin	Luminance of the display screen when the input signal corresponding to that portion of the screen is at the lowest level, e.g., level 0 for an 8-bit display.
Maximum Luminance (Lmax)	Luminance of the display screen when the input signal corresponding to that portion of the screen is at the highest level, e.g., level 255 for an 8-bit display.
Luminance Stability	Measure of variation in luminance as a function of the fraction of screen area that is being lit (i.e., the fraction of the frame time in which the electron beam is actually turned on).
Luminance Uniformity	Measure of how luminance varies across the screen. Luminance should be as uniform as possible.
Resolution:	Measure of the ability to delineate picture detail; i.e., ability to distinguish two adjacent spots on the screen.
Screen Gain	The ratio of the reflected or transmitted luminance of a projection screen to the luminance of a Lambertian reflector which reflects all of the incident light uniformly in all directions. Screen gain is usually specified for the viewing angle that is perpendicular to the surface of the screen.
System Gamma:	The slope of the curve in a log-log plot of output luminance vs. input drive *at the monitor terminals*. Note that this definition includes any modification to the drive curve by the internal boards on the monitor – thus the term *System Gamma.*
Warmup Characteristic:	Time required for the luminance to stabilize at some predetermined value (typically ±1%).

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